



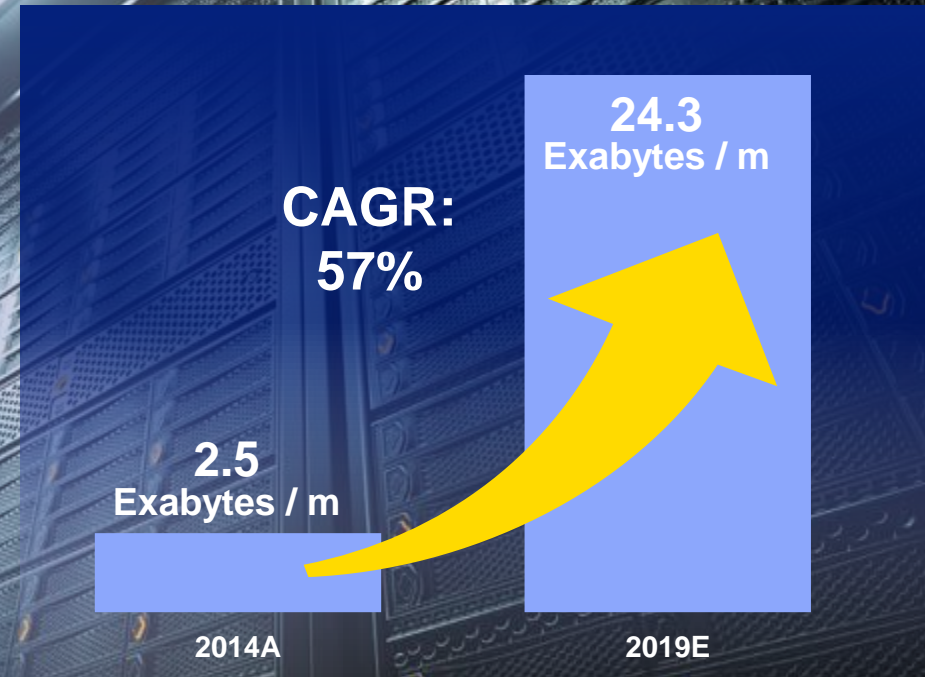
10G | 5G | 2.5G | 1G |
100M PHYSICAL LAYER
PHY

HOT CHIPS 2015 CONFERENCE

RAMIN SHIRANI
RAMIN FARJAD-RAD



MEGATRENDS DRIVING NEED FOR NEXT GENERATION CONNECTIVITY



Source: Cisco VNI Report, 2015

- Transition to Next Generation Ethernet Solution Required
- Must Alleviate Critical Bandwidth Constraints in Global IT Infrastructure

ENTERPRISE NETWORK STRUCTURE

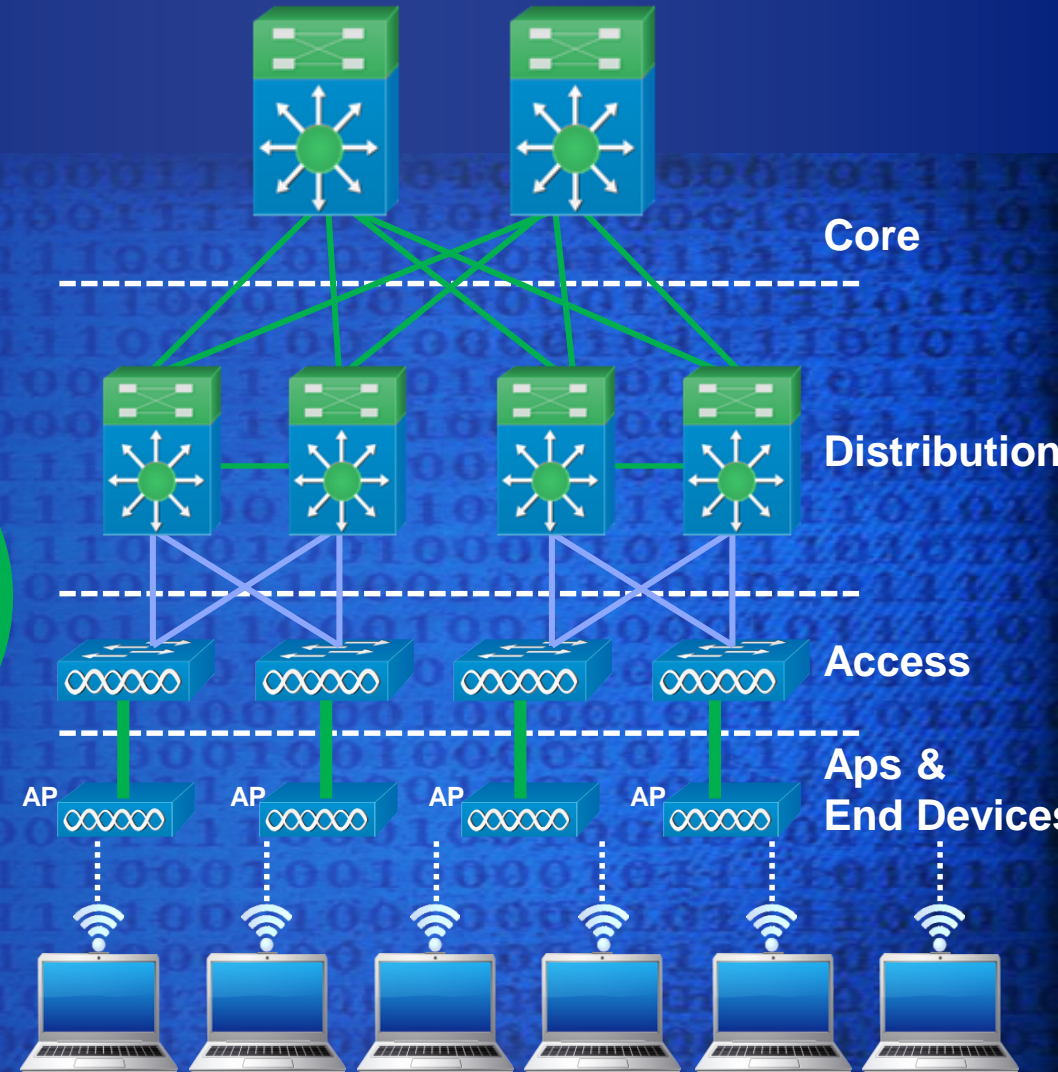
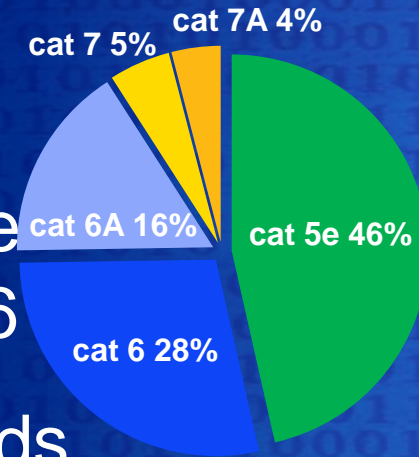
- Enterprise networks follow:
Three Tier Design Approach

- Proven
- Widespread
- Stable topology

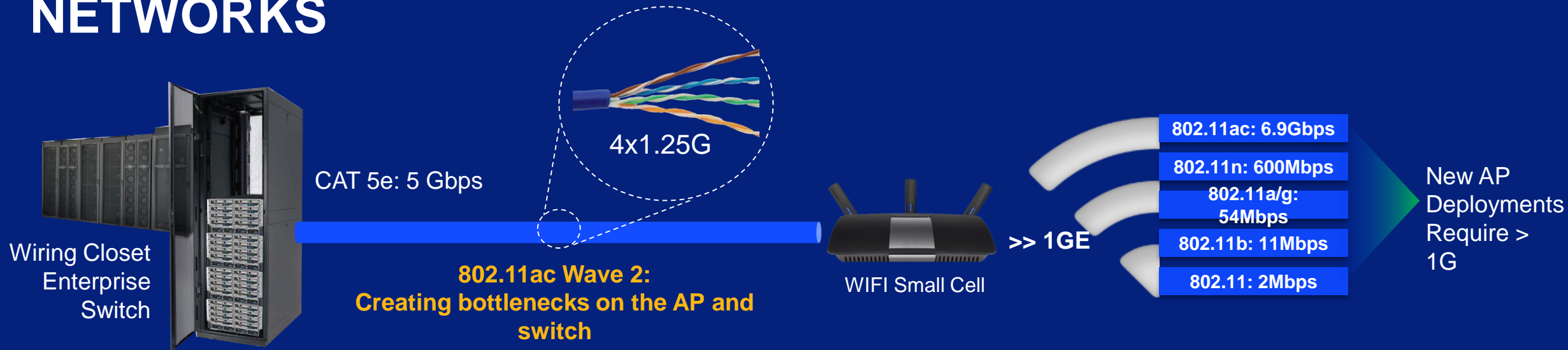
- More than 70% of enterprise campus wiring = Cat5e/Cat6

- Aquantia ICs increase speeds on Cat5e/Cat6 links:

- Enterprise access switches
- Wireless APs



WLAN UPGRADE CREATING BOTTLENECK IN ENTERPRISE NETWORKS



- Legacy wireless access connections dominated by 1000Base-T - 30W PoE
- Wireless transition to 802.11ac (Wave 1 & Wave 2) needs:
 - Multi-Gigabit speeds + 60W UPoE
- Aquantia's 28nm ICs were designed for 5 speeds on 100 meters:
 - 10G Cat6A and Cat7
 - 5G/2.5G/1G/100M on Cat6A, Cat6, and Cat5e

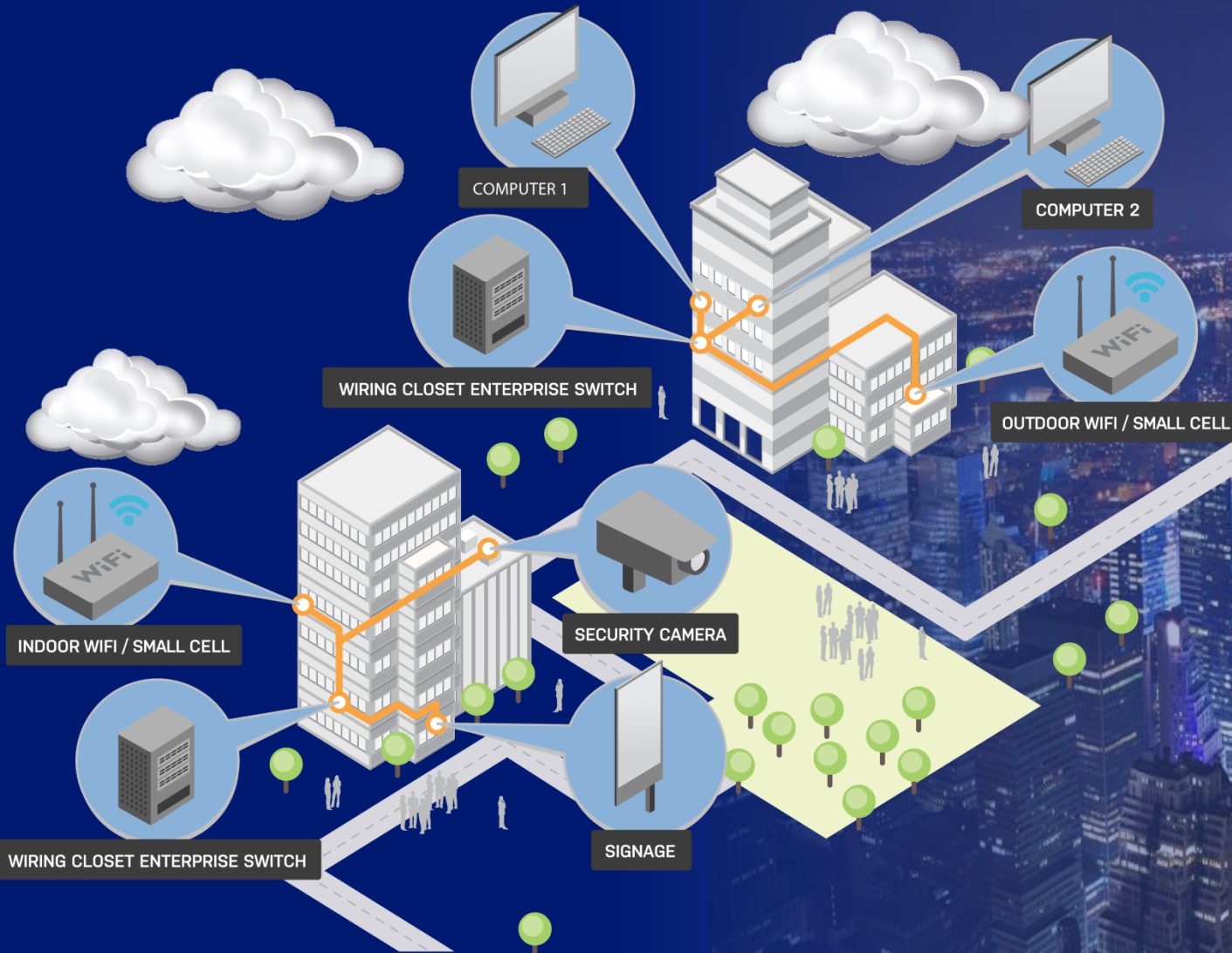


Aquantia: founding member

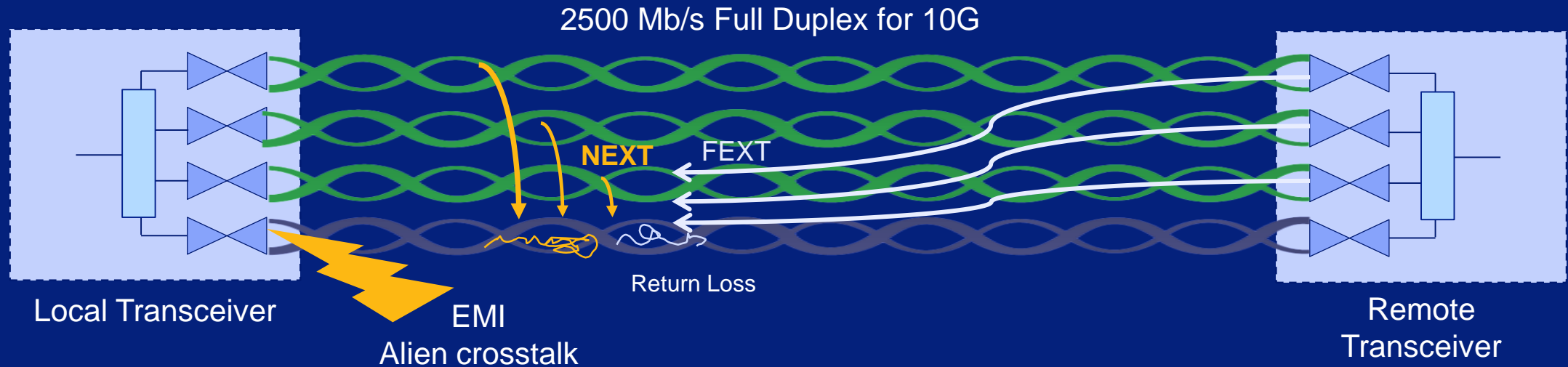
- 2.5G/5G electrical & interoperability specifications

AQUANTIA[®]

MULTI-GIGABIT APPLICATION SPACE



1000BASE-T | 2.5G | 5.0G | 10GBASE-T SIGNALING



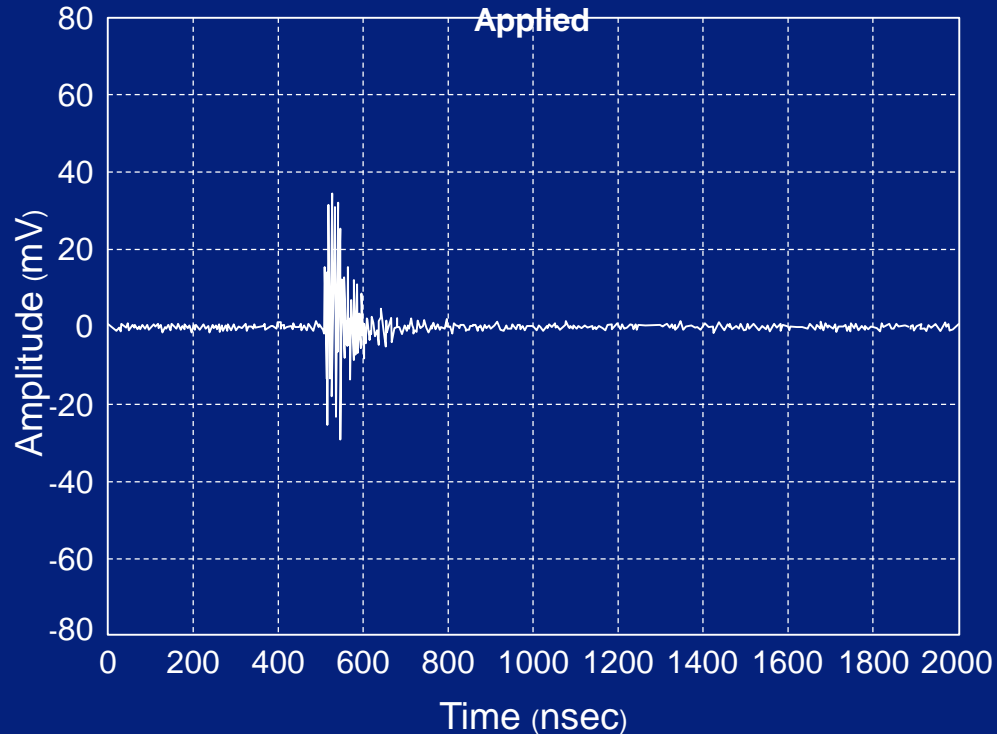
- Duplex transmission → Echo power >> Received power
- Self Near End (NEXT) and Far End (FEXT) Crosstalk
- Alien crosstalk noise from adjacent cables
- Environment specific interferences (e.g. Enterprise)



ESD IMPULSE NOISE IN ENTERPRISE

Impulse Noise from Mesh Desk Chair Internal ESD at
2m (Cat 5e UTP)

V_{ptp} = 63 mV, Span (90%) power) = 81 nsec, 220 MHz LP Filter



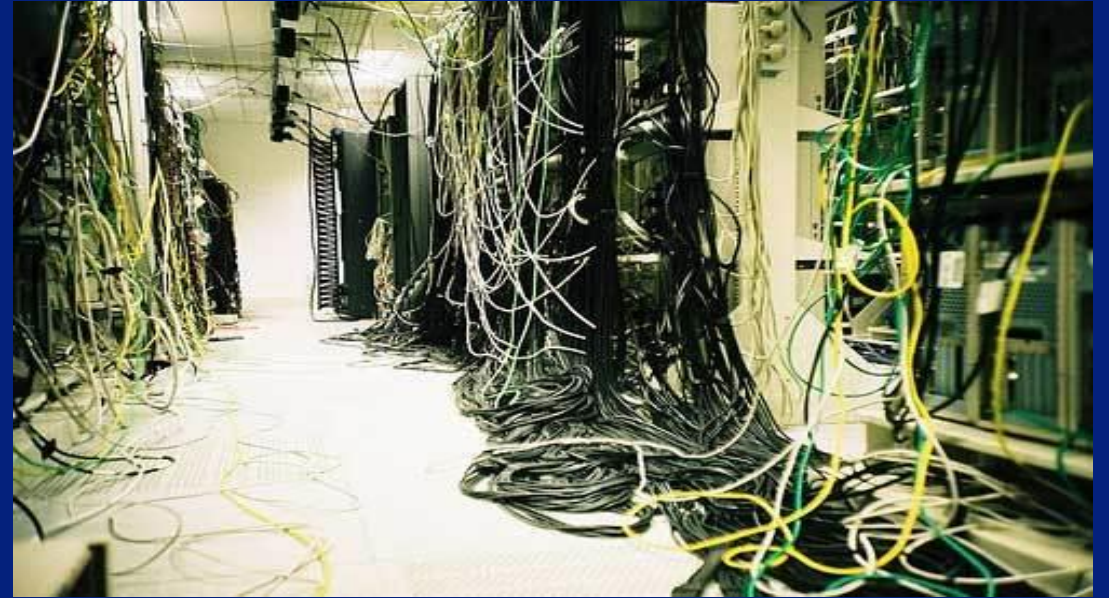
Example of ESD Differential noise in
enterprise

- ESD events are generally band pass (80MHz to 200 MHz)
 - Low duration, frequent in enterprise that interferes with the operation of data rates above 1000BASE-T
 - Such interference events increases the bit error rate of an otherwise properly operating data link
 - Example enterprise space: Visitors taking a seat & getting up in a public library

CABLING QUALITY: DATA CENTERS VS. ENTERPRISE

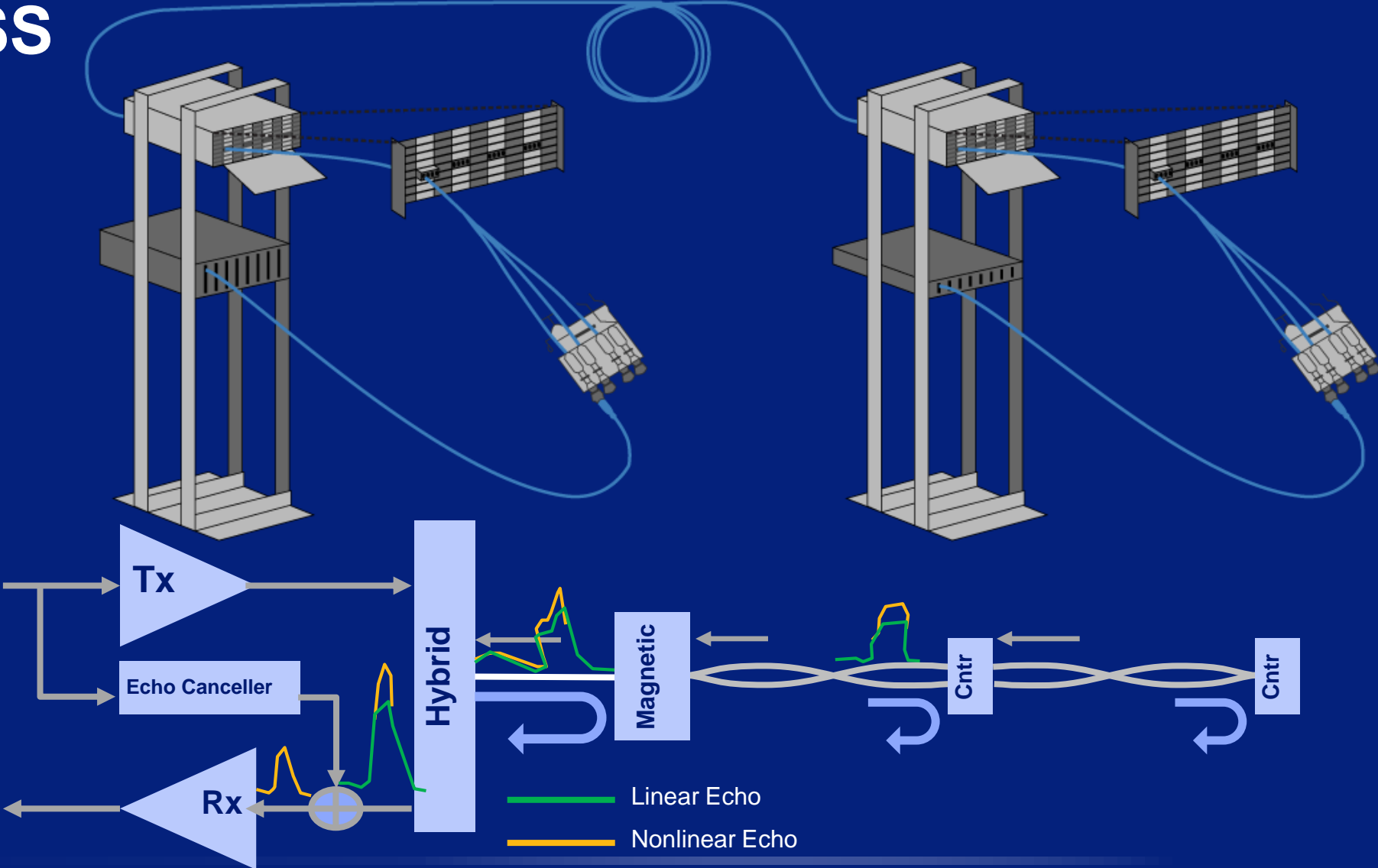


- Next generation Data Centers are built cleanly from scratch with new cabling

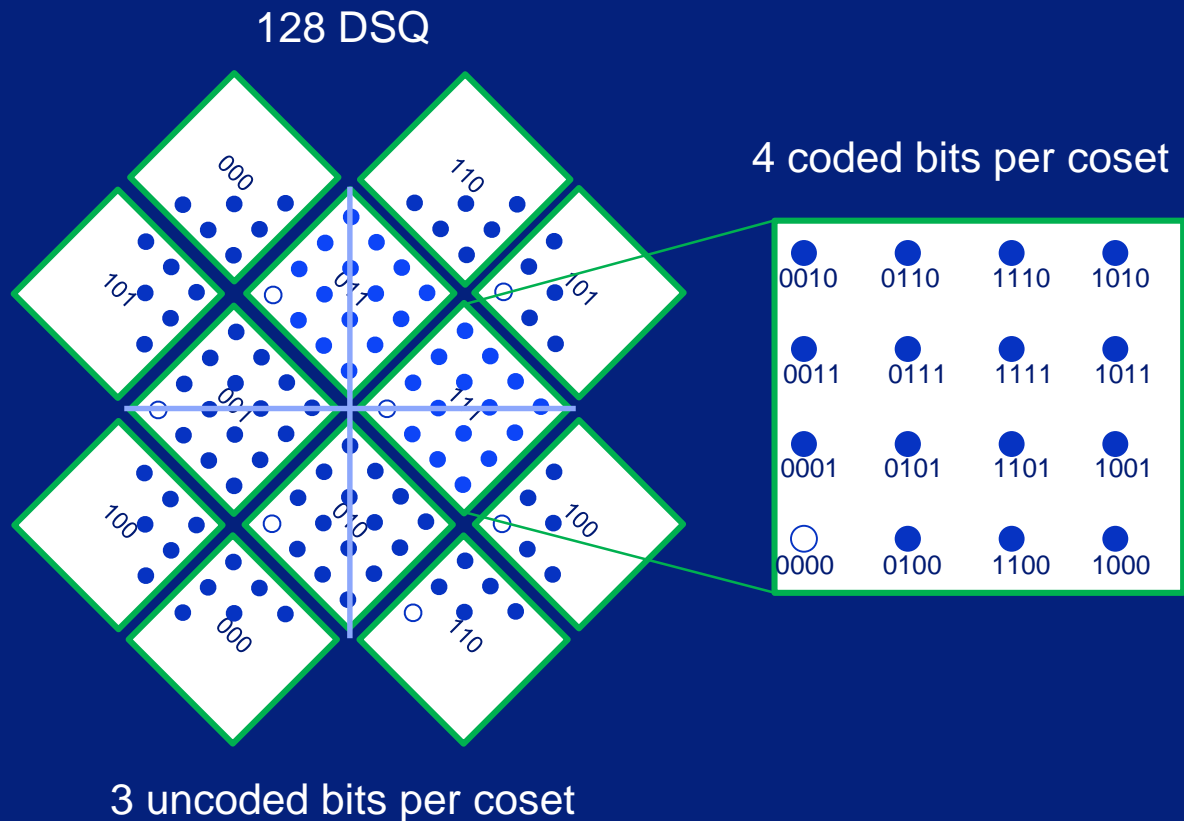


- Goal in Enterprise is to extend the life of existing cabling to the next generation
- Many enterprise cabling setups are qualified only up to 1000BASE-T (<62MHz)
- Poor cable return loss leads to large impulse reflections in full-duplex links

LOSS



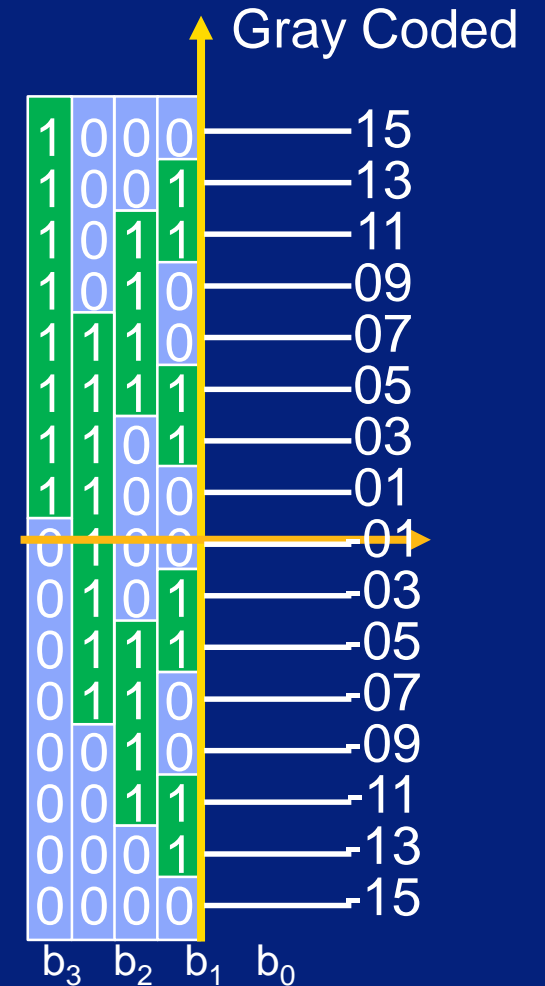
10GBASE-T CODING



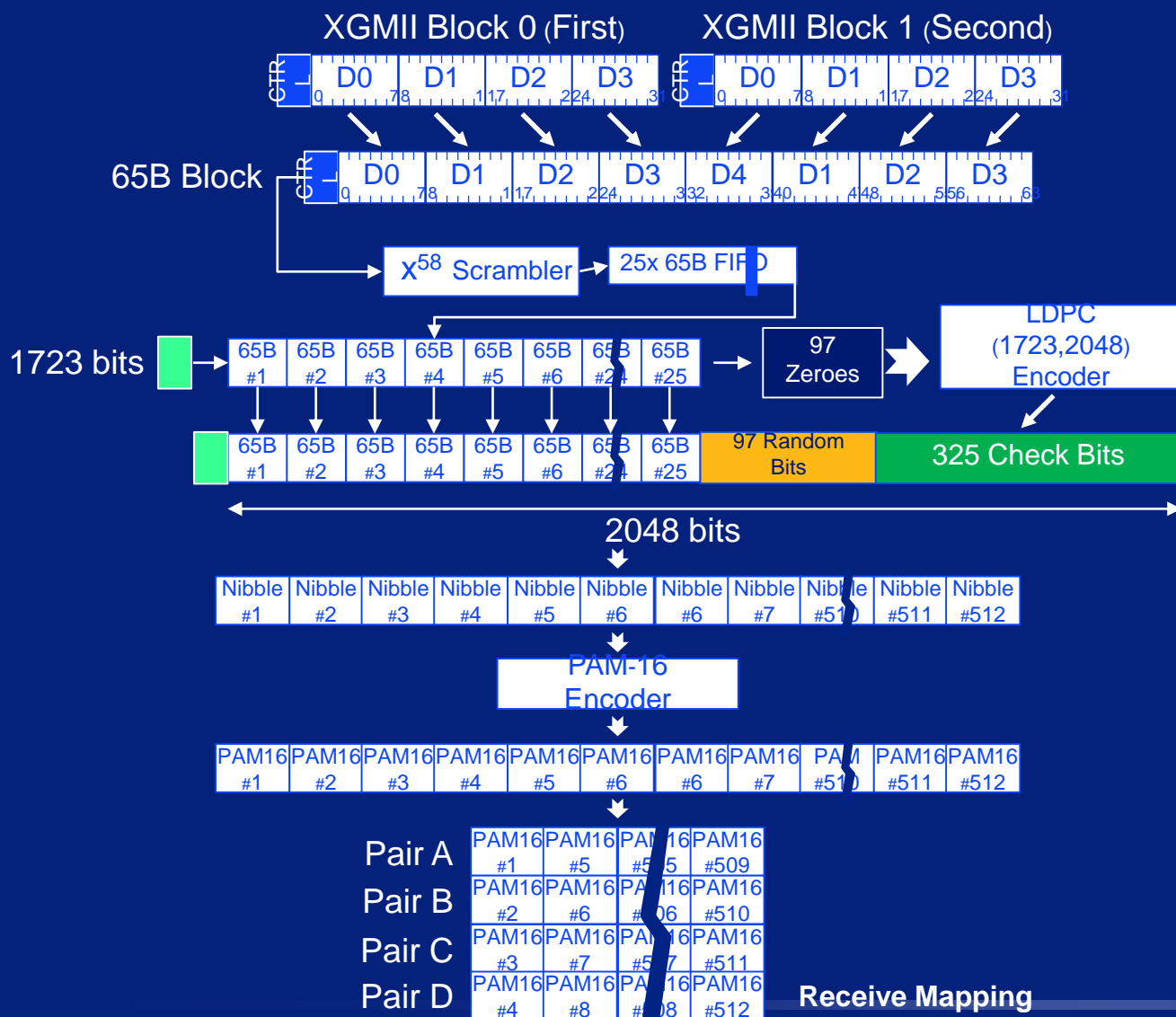
- 10GBase-T DSQ128 allows 128 combinations
- There are 7 bits/DSQ128 symbol
 - 3MSBs are uncoded
 - 4LSBs are FEC coded through LDPC
- These 3 uncoded bits are most vulnerable to large impulse noise
 - Dominant in Enterprise

HOW TO PROTECT ALL TRANSMIT BITS WITH LDPC?

- Gray-coded PAM16 signaling
 - PAM 16 = 4 bits per symbol
 - 8bits vs 7bits per 2 symbols
 - Additional bits per frame used to protect uncoded bits by same LDPC machinery
 - Combination of LSB & MSB bits in the LDPC Frame
 - Higher number of encoding bits improves FEC gain by over 1dB
- Robust to non-stationary impulse noise & AFE imperfections
- Otherwise, a scaled version of 10BASE-T

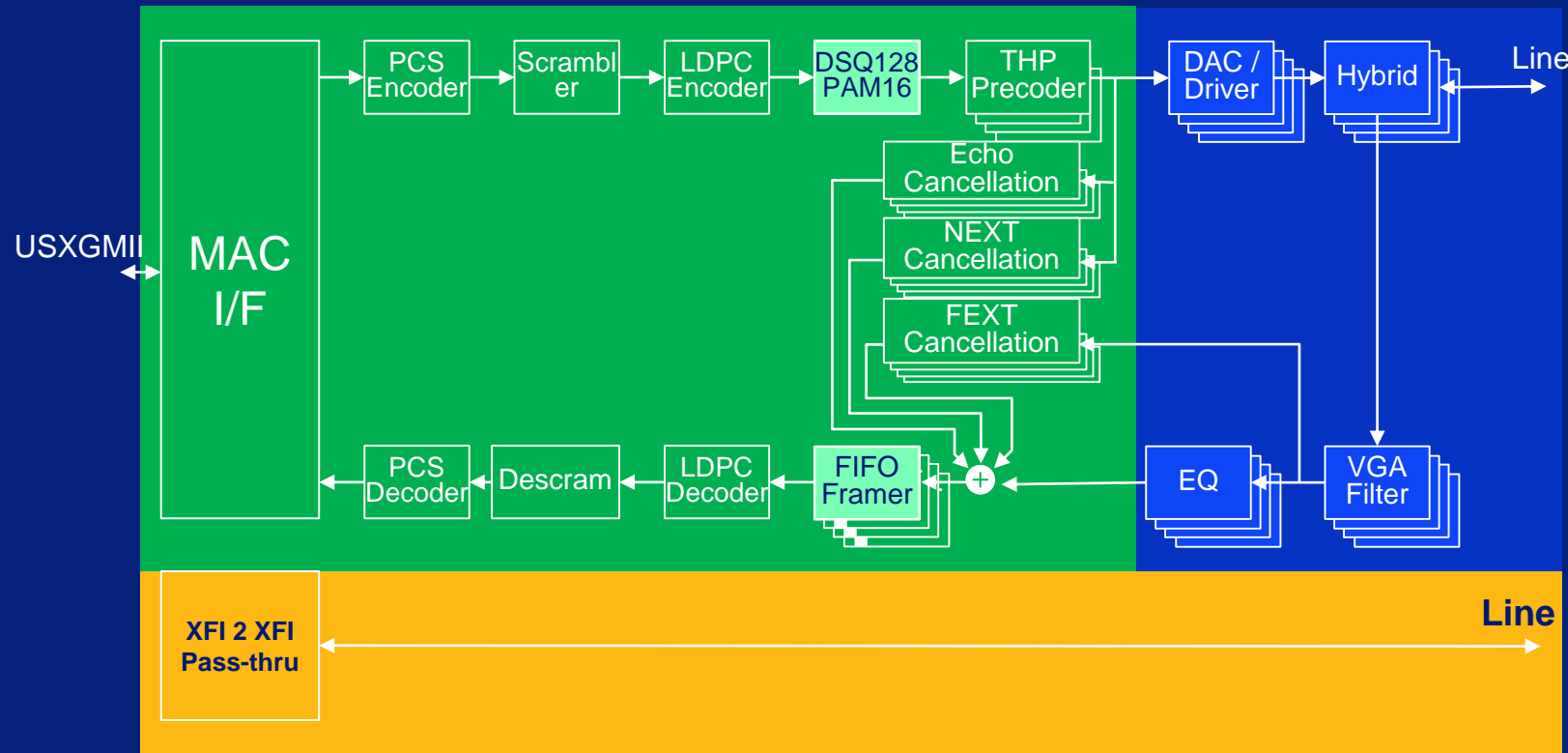


DATA MAPPING



- 5Gb/s via fully LDPC coded PAM 16 running at 400Ms/s
- 2.5Gb/s via fully LDPC coded PAM 16 running at 200Ms/s
- Fully Encoded PAM16 An FEC extended to uncoded bits
 - Removes errors caused by noise spikes
 - Provides additional margin for ESD events
 - Relaxes the PHY transmit linearity spec significantly
 - Relaxes the magnetic RL requirement

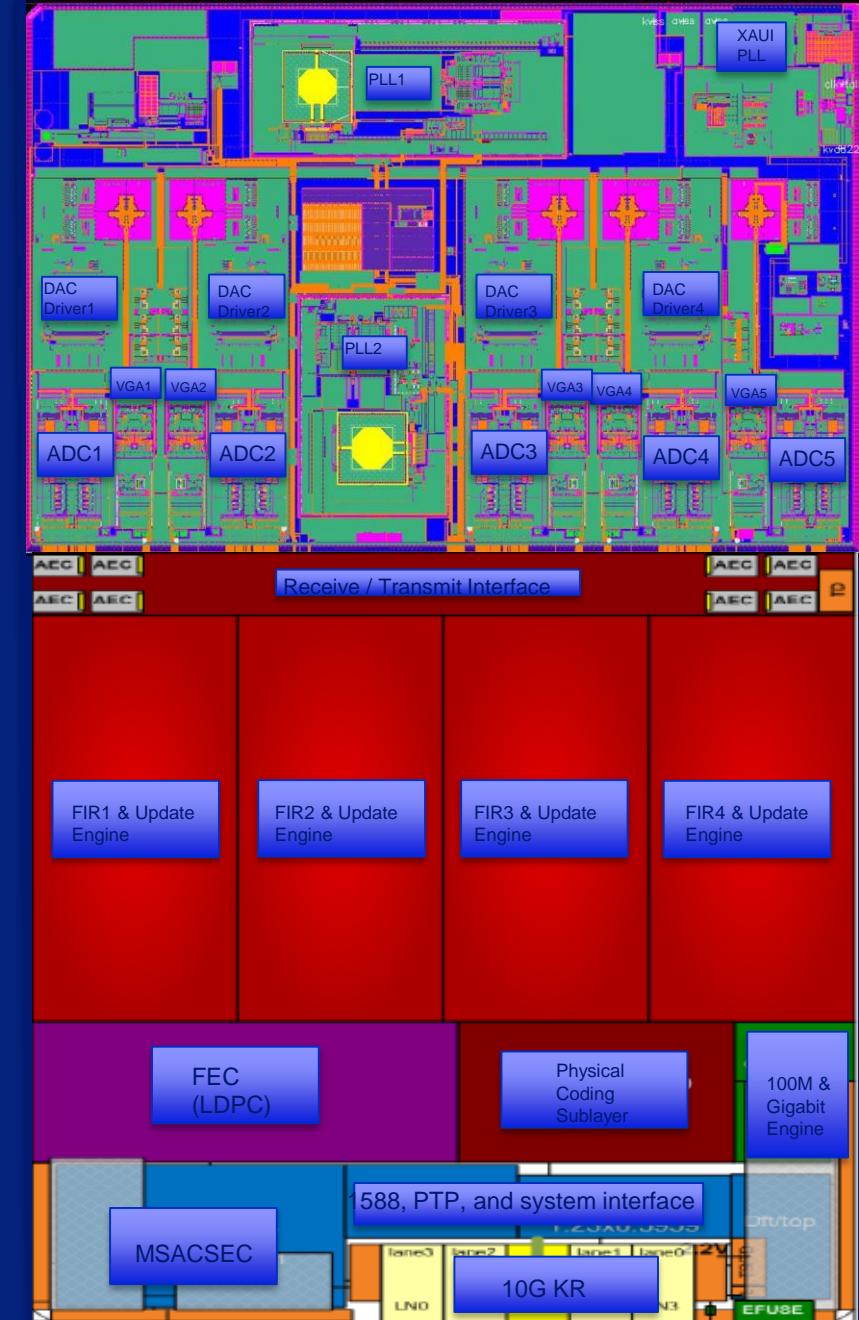
AQUANTIA PHY BLOCK DIAGRAM



- PHY analog & digital blocks architected to power scale proportional to data rates 10G/5.0G/2.5G
 - Analog power saving achieved by modifying performance requirement
- USXGMII SerDes runs at fixed 10Gbps at all PHY data rates to simplify system interface

AQUANTIA PHY CHIP (28nm)

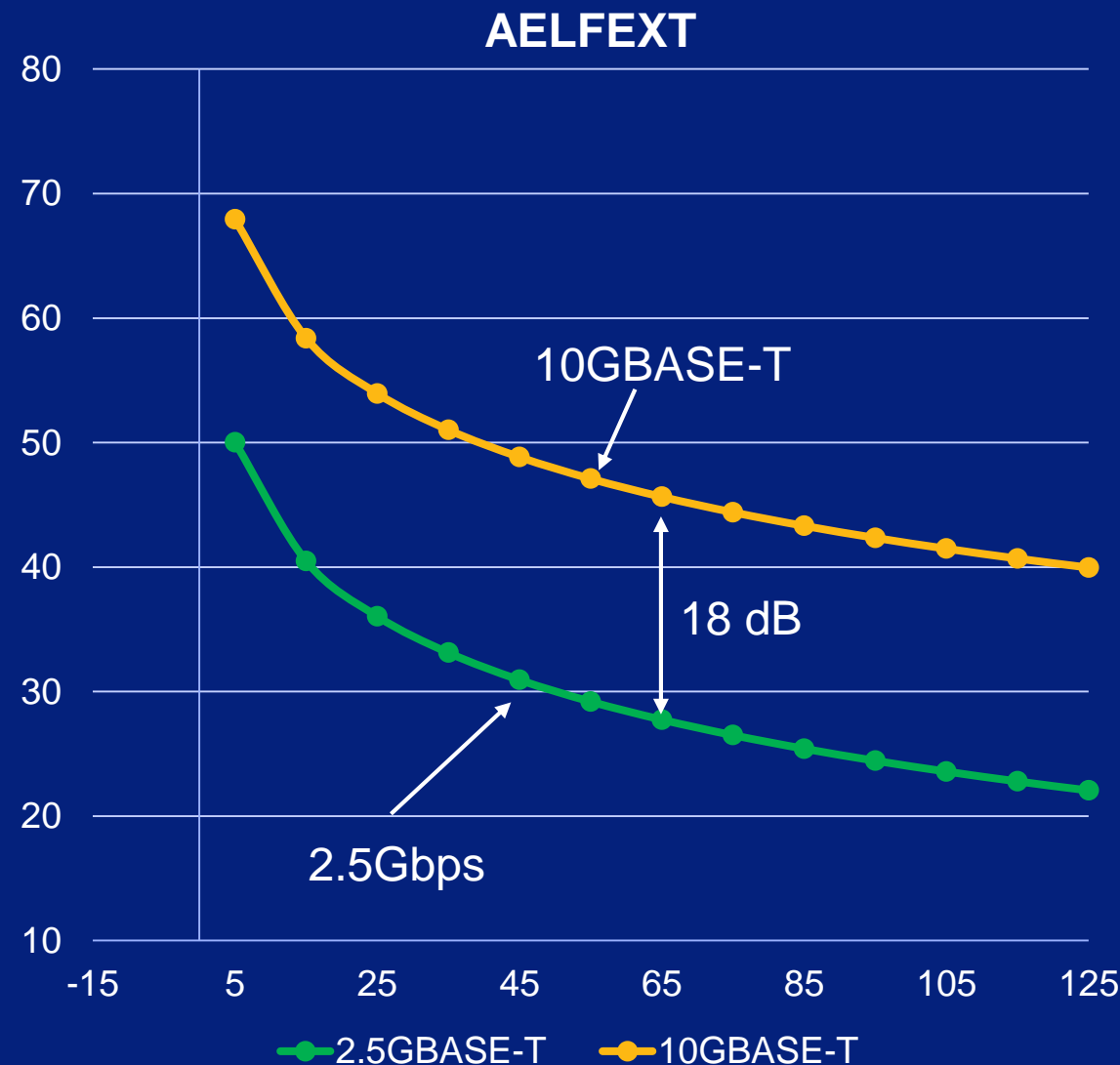
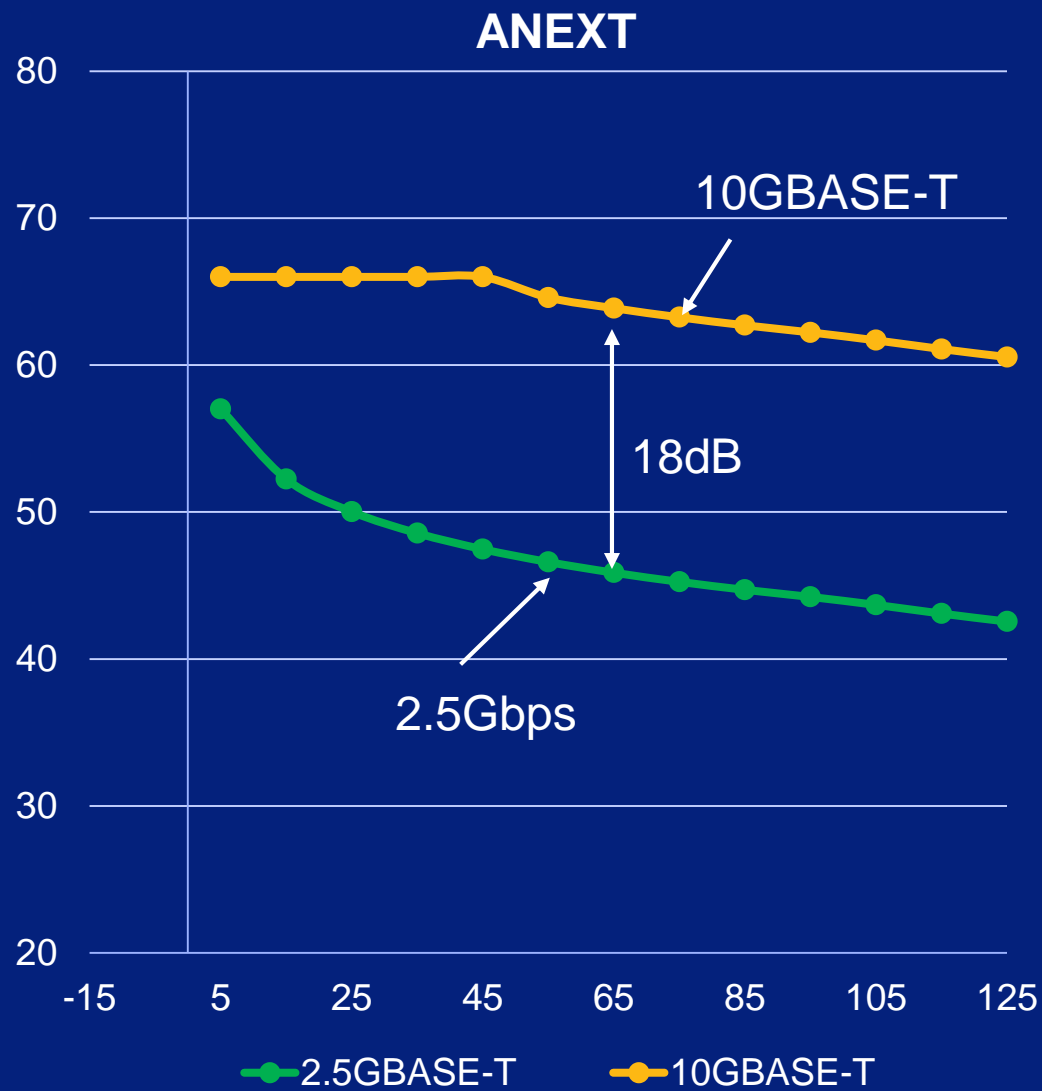
- Analog frontend with 5 receive channels and 4 transmit channels
 - 5th receive to sense/cancel in band RFI
 - Combination of LC & ring PLLs to cover all required speeds
- High-Gain LDPC FEC → 128DSQ: ~8dB, PAM16: >9dB
- Modular FIR filters combined with convergence engines
- Supporting:
 - 1588 & PTP Features, Energy Efficient Ethernet (EEE), MACSEC
- Chip Area: 40mm²
- Power: 1W, 2W, 3W for 2.5G, 5G, 10G



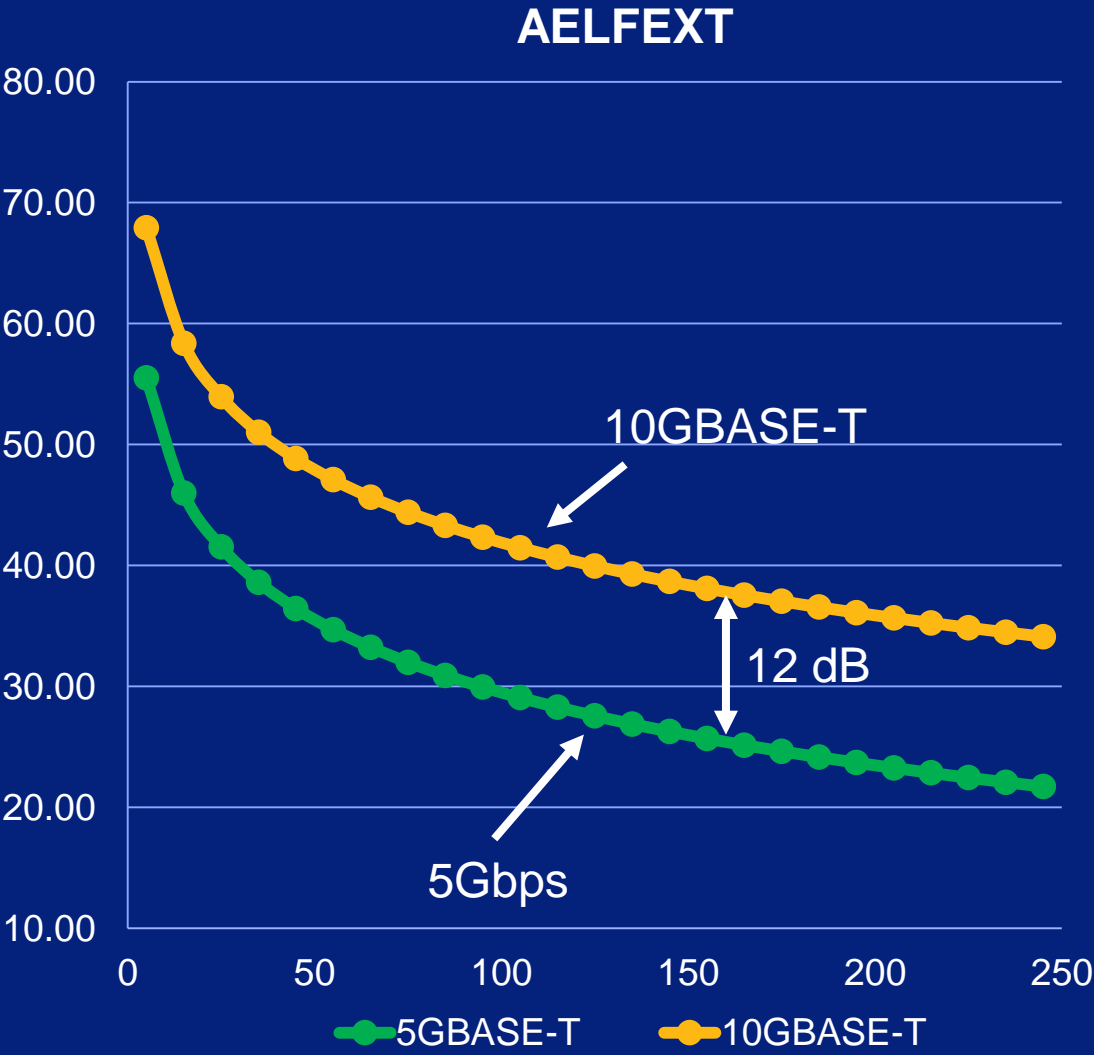
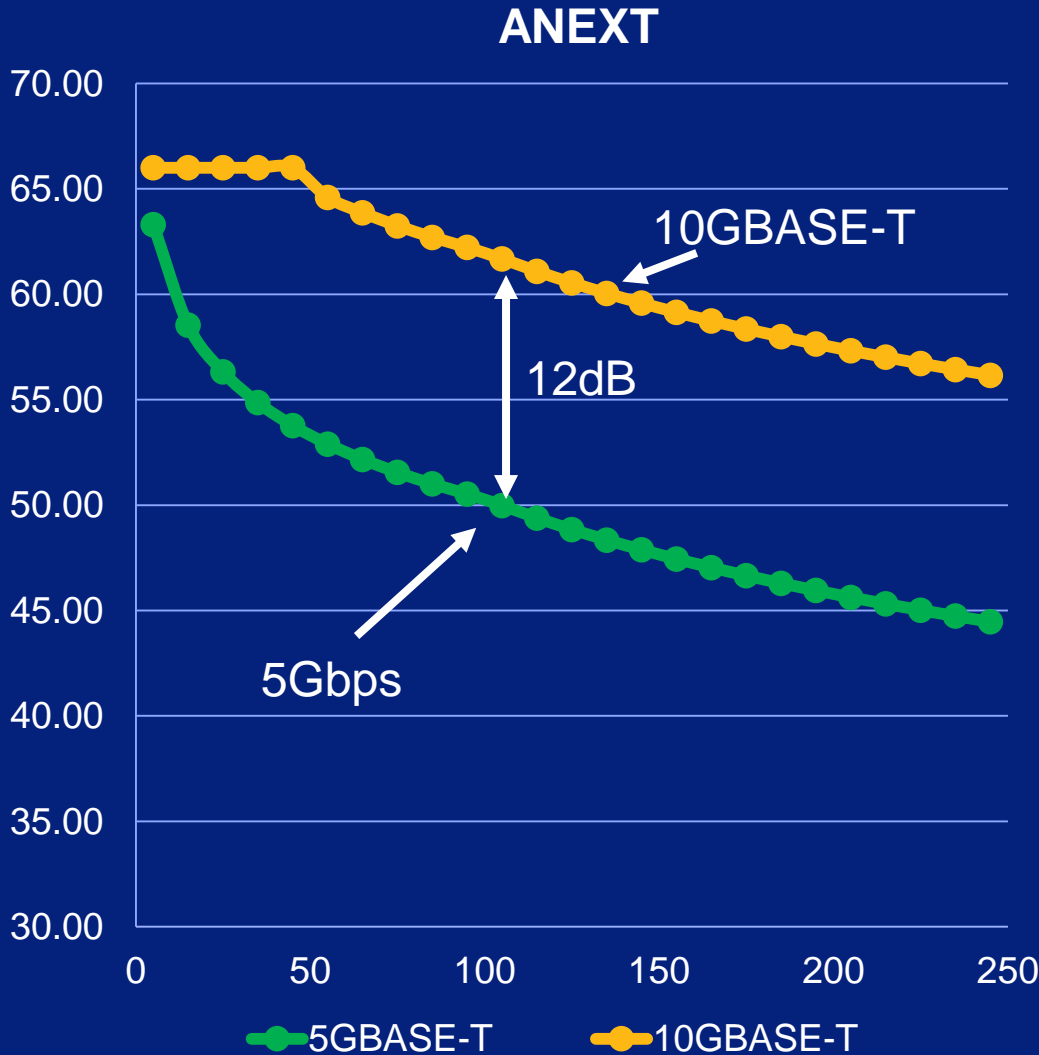
IEEE PERFORMANCE SPECIFICATION FOR 2.5G | 5.0G

- 2.5 Gb/s PHY specified for operation over
 - Up to at least 100m on four-pair Class D (Cat5e) balanced copper cabling on defined use cases and deployment configurations
- 5 Gb/s PHY specified for operation over
 - Up to at least 100m on Class E (Cat6) balanced copper cabling on defined use cases and deployment configurations
 - Up to 100m on Class D (Cat5e) balanced copper cabling on defined use cases and deployment configurations

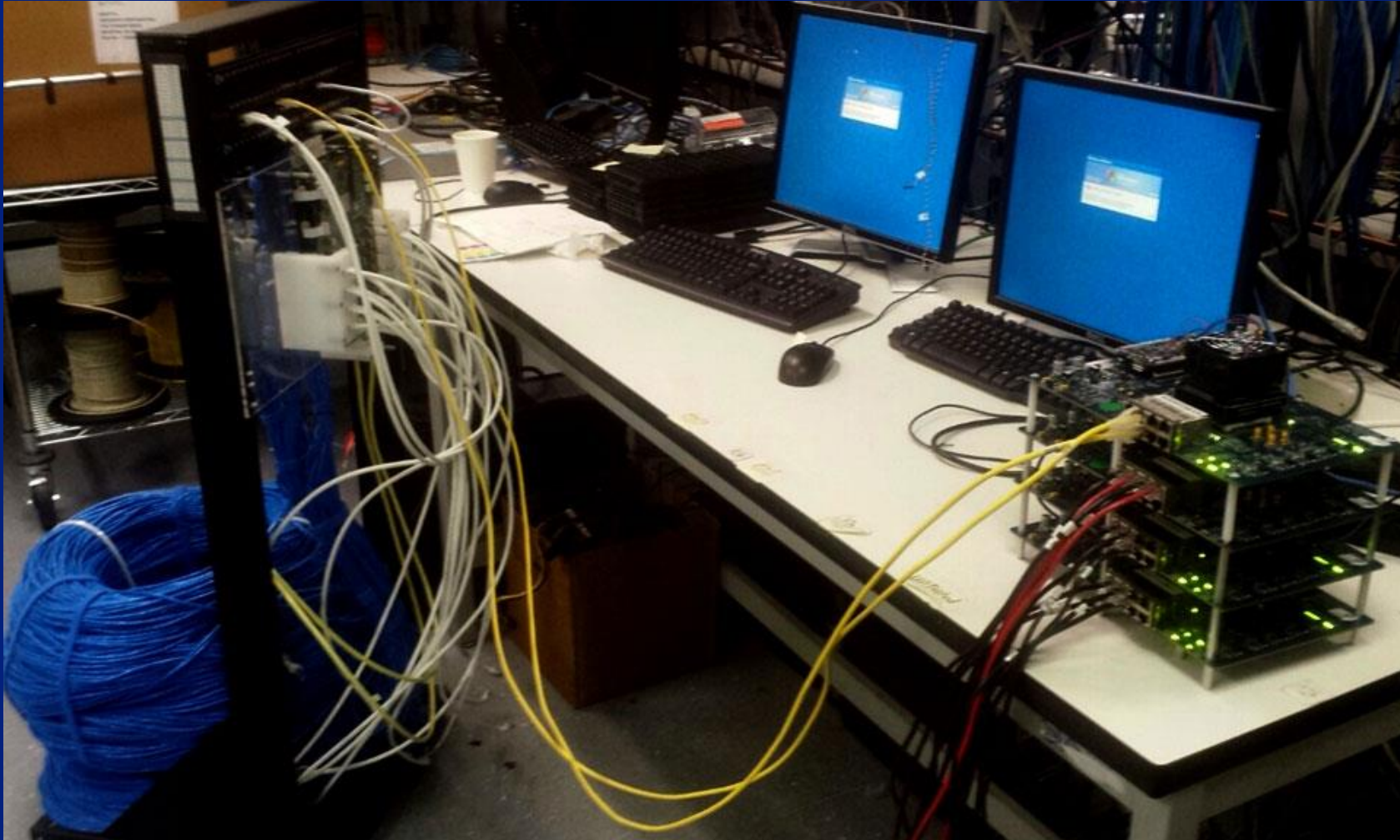
2.5Gbps ALIEN X-TALK LIMIT LINES (BER<1E-12)



5.0Gbps ALIEN X-TALK LIMIT LINES (BER<1E-12)



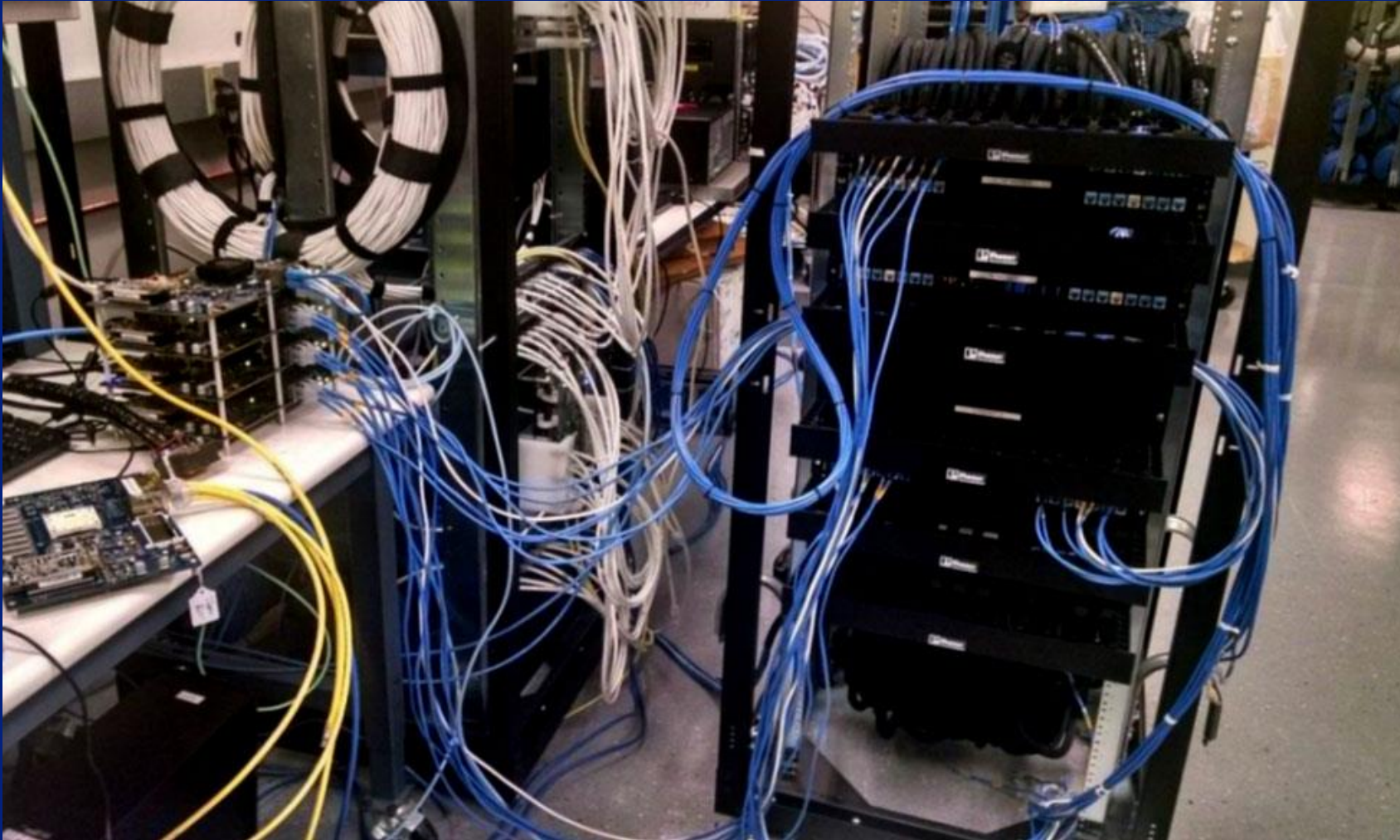
Cat5e & Cat6 SIGNLE-CABLE PERFORMANCE SETUP



2.5Gbps | 5.0Gbps PERFORMANCE OVER SINGLE CABLE

- 2.5Gbps reach for $BER < 1E-12$
 - Over ~195m of Cat5e
 - Cable IL = ~42dB@100MHz → **18dB** exceeding Cat5e limit line
- 5.0Gbps reach for $BER < 1E-12$
 - Over ~125m of Cat5e
 - Over ~135m of Cat6
 - Cable IL = ~43dB@250MHz → **9dB** exceeding Cat6 limit line

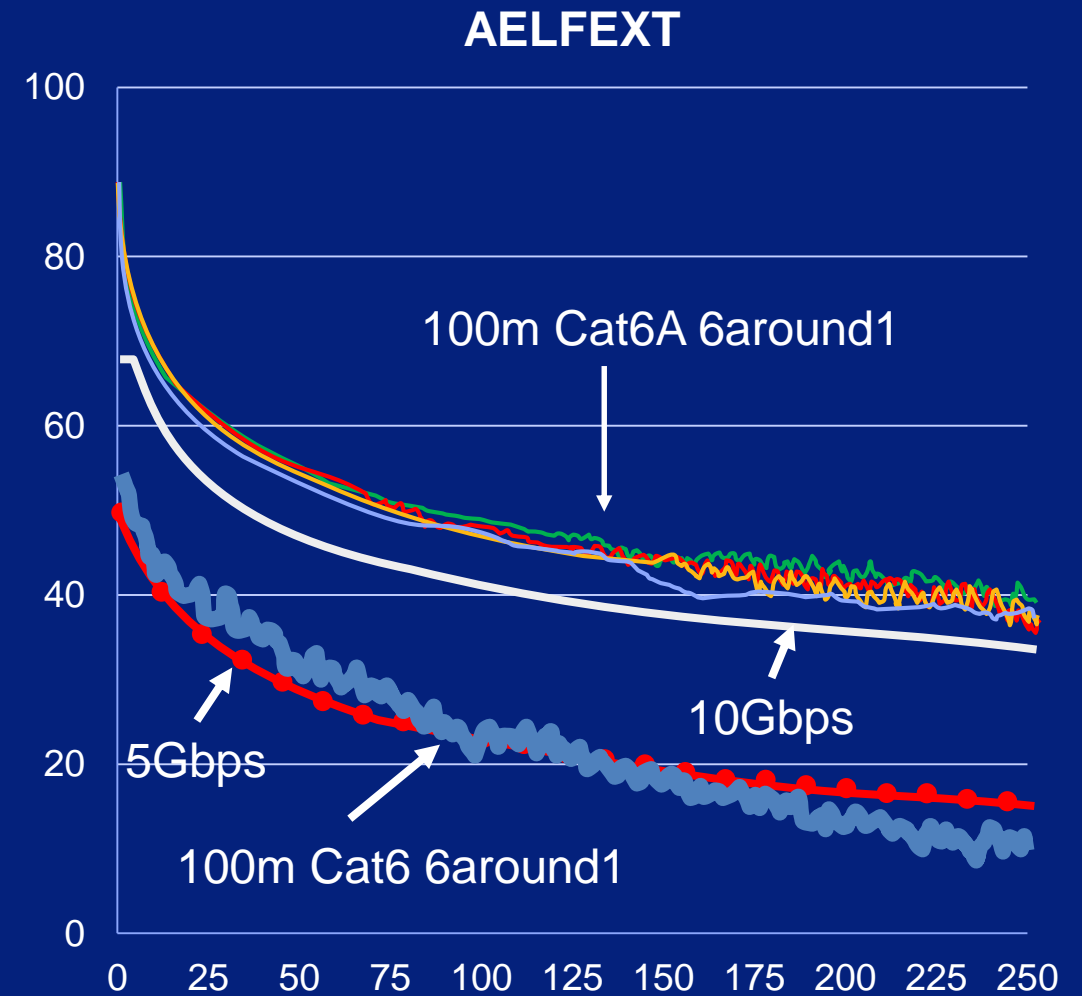
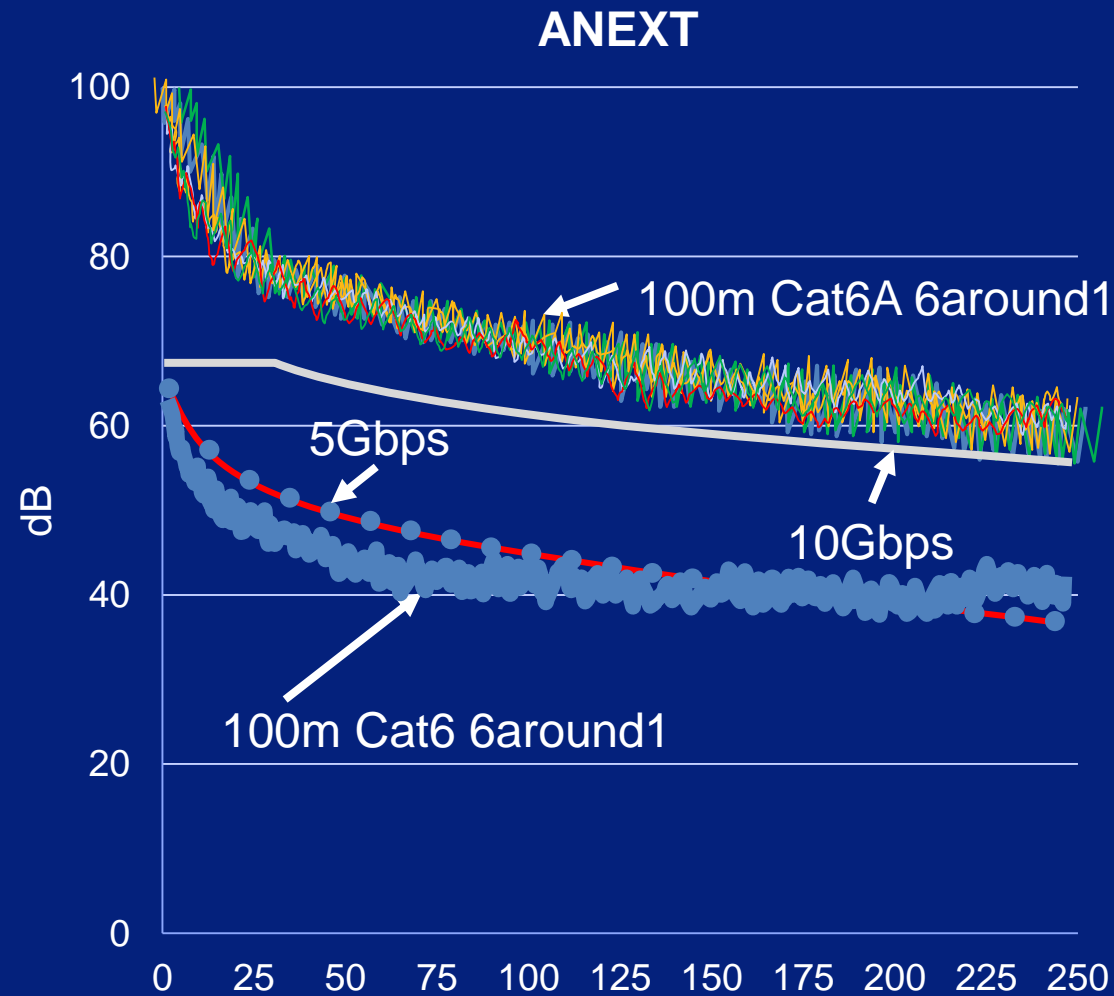
6around1 CABLE COMPLIANCE RACKS (Cat6A/Cat6/Cat5e)



2.5Gbps/5.0Gbps PERFORMANCE On 6around1 CABLE

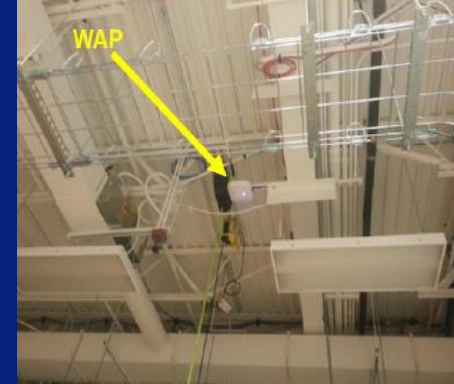
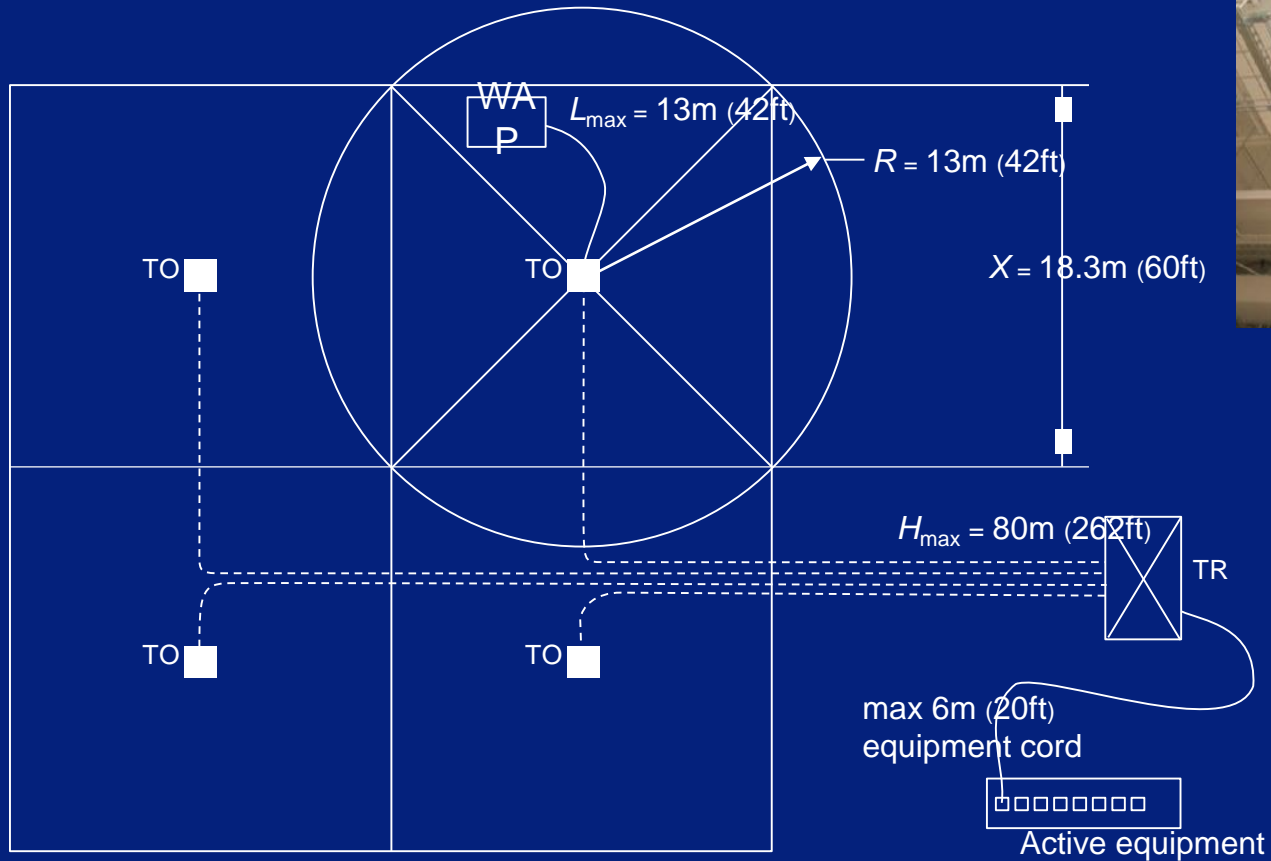
- 2.5Gbps reach for $BER < 1E-12$
 - Over ~135m of Cat5e (Full length 6@1)
 - Cable IL = ~29dB@100MHz → Margin to CAT5e Limit= **-5dB**
- 5.0Gbps reach for $BER < 1E-12$
 - Over ~100m of Cat6 (Full length 6@1)
 - Cable IL = ~32dB@250MHz → Margin to Cat6 Limit= **2dB**

ALIEN X-TALK OF FULL 100M 6around1 CABLE SETUPS



IEEE DEFINED WAP ENTERPRISE USE CASE

Typical Uniform Cell Size



Cell sizing (wireless access points placed anywhere inside the cell)

<http://www.ieee802.org/3/NGBASET/email/pdfy0VqAHwIW1.pdf>

6around1 CABLE BUNDLED CONFIGURATIONS

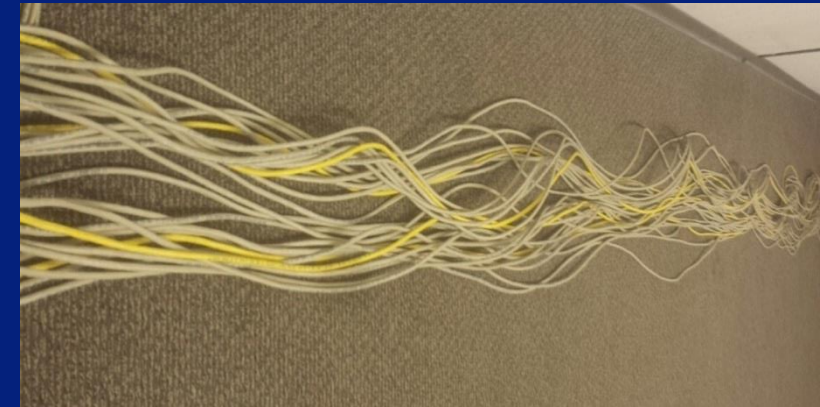


- 6@1 Bound by Binders Across the Cable



- 6@1 Tied by Straps every 4ft (Most Common)

→ ~9dB improvement of alien xtalk



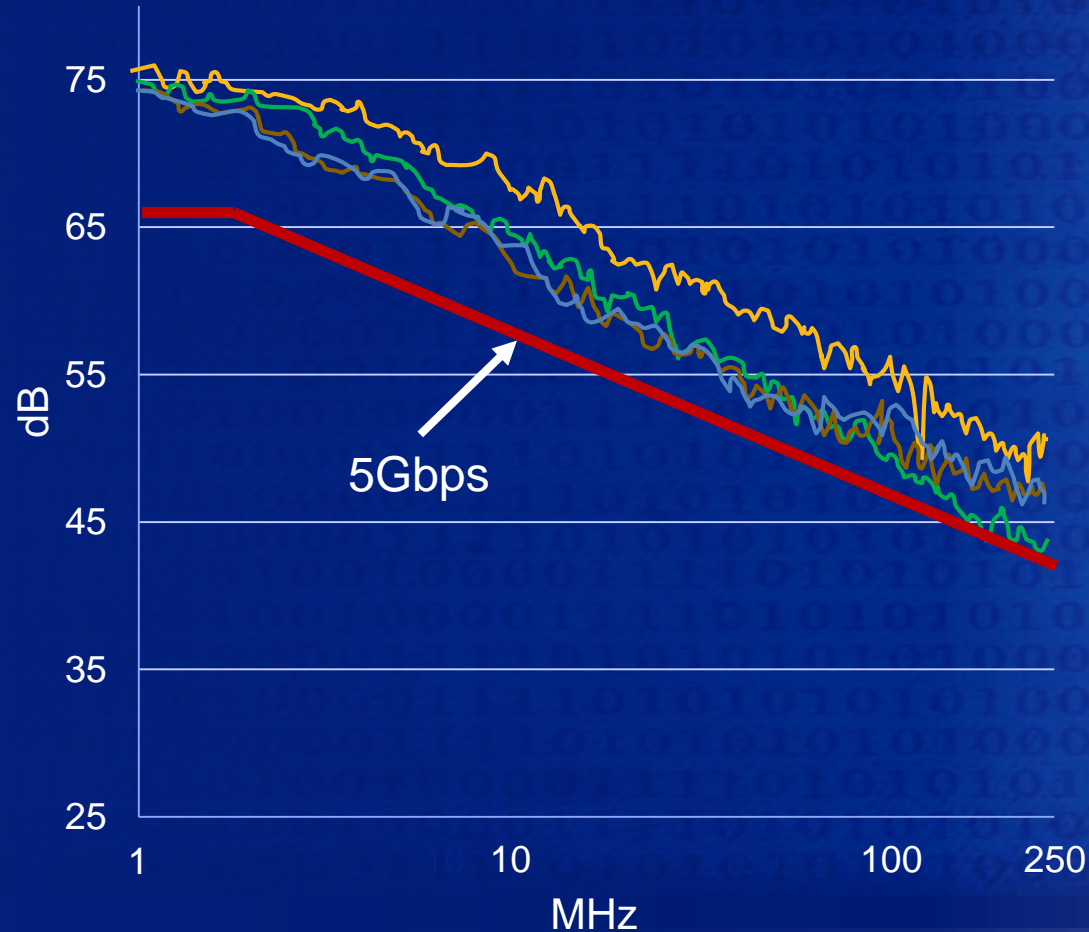
- Unbound Cables (e.g. Conduits)

→ 20dB improvement in alien xtalk

http://www.ieee802.org/3/10GBT/public/mar03/vanderlaan_1_0303.pdf

Cat6 ALIEN X-TALK: TYPICAL ENTERPRISE INSTALLATIONS

Category 6 “Alien” Power Sum NEXT
(plenum bound)



- Configuration:
 - 24 Cat6 Cables
 - Tied every 5 feet
 - Tied length <80m
 - Victim at center of bundle
 - Routed to the ceiling
- X-Talk Measurement meets the target 5Gbps alien xtalk limit lines!

http://grouper.ieee.org/groups/802/3/tutorial/nov02/tutorial_2_1102.pdf

CONCLUSION

- The ever growing data requirements in the cloud and mobility are creating a bandwidth constraint in global IT infrastructure
- In 2012, Aquantia focused on adding 2.5G/5G speeds on Cat5e/Cat6 Links to address the next generation wireless access bottleneck
- Aquantia's five speed ICs (single, dual, and quad) are the only commercially available NBASE-T compliant ICs since 2013
- Five speed ICs from Aquantia has been shipping in large volumes in all major switch and AP platforms since 2014



AQUANTIA®